IIW COMMISSION VC – ULTRASONICALLY BASED WELD INSPECTION

E. Sjerve
IRISNDT, Edmonton, Alberta, Canada.

Abstract: The IIW is an active organization in the area of weld based topics. Within a structure of 15 independent commissions and another group of working committees, the IIW gathers together leading people from the perspectives of fabrication, maintenance, and inspection to discuss and forward the state of the art in welding. Within this framework, Commission V is dedicated to quality assurance of welded forms. This paper will describe the current, the past and the expected future activities of Sub-commission VC, ultrasonic based weld inspection.
The best known past activity in Sub-commission VC is the design and implementation of the IIW test block, which is used extensively in industry to set calibration parameters and ultrasonic sensitivity. Currently, the two main areas of focus are the publication of IIW Handbooks in the areas of inspection of austenitic welds and automated ultrasonic inspection (AUT). Austenitic and DMW weld inspection is of interest due to the difficult grain structures that can be encountered, and the resulting problems it causes for ultrasonic inspection. AUT inspection is also of interest due to the large number of companies providing this service. Lastly, future areas of work are discussed, which include re-qualification of the IIW block to provide more uniform properties for setting inspection sensitivity and phased array inspection.

Introduction: The IIW is an international organization that works in all areas that are of concern for welded products. It has been in existence since 1948 when it was first formed by welding institutes or societies in 13 countries to produce more rapid scientific and technical progress in the area of welding. The long term goals of the organization are to organise the exchange of scientific and technical information and provide for the transfer of knowledge related to these techniques. The organization has consistently expanded into new areas as technology has advanced, with some of the newest areas of focus being the joining of plastics and composites, the use of computers in process control and the consideration of new inspection techniques. In the past, experts at IIW have been responsible for much of the technical basis for many of the welding standards issued by ISO. Since 1989, the IIW has been recognized by the ISO as an International Standardization Body to prepare the final texts of international welding standards. This allows the IIW to put forth standards without having to go through the standard ISO pre-standards process.

The IIW is comprised of international groups of specialists who collectively study various issues related to welding. All of these people are members in the General Assembly, which is then divided into Commissions that focus on particular areas. Out of the Commissions come recommendations, reports and guidelines that represent the consensuses of the working groups. There are roughly 400 technical papers produced each year by the IIW, of which roughly 40 are published in the IIW journal, Welding in the World.

The IIW is organized into a total of 15 commissions and a number of other working committees. All of the commissions are focused on one particular aspect of welding, and these commissions are listed below in Table 1. Each commission is lead by a chairman who is responsible for the technical direction of the group within the overall IIW mandate. Within each commission, there are typically a number of smaller sub-commissions or working groups that focus on specific topics. An example of this is with commission V, which is comprised of a total of 5 sub-commissions and two working groups focused on specific aspects of quality assurance of welded products[1].

Within each sub-commission there are sometimes working groups that focus on specific projects. These groups typically have a number of very technically oriented experts in the relevant field that are working towards a solution to a technical issue. It is these working groups that produce the documents that the IIW is known for, and that in the end become the standards that are useful to industry.

Commission Number	Description
I	Brazing, Soldering, Thermal Cutting…
II	Arc Welding and Filler Metals
III	Resistance and Solid State Welding…
IV	Power Beam Processes
V	QC and QA of Welded Products
VI	Terminology
VII	Authorization and Qualification
VIII	Health and Safety
IX	Behaviour of Metals Subjected to Welding
X	Structural Performance of Welded…
XI	Pressure Vessels, Boilers and Pipelines
XII	Arc Welding Processes and Production
XIII	Fatigue of Welded Components…
XIV	Education and Training
XV	Design, Analysis and Fabrication of…
XVI	Polymer Joining and Adhesive Technology

Table 1: IIW Commission Structure

Commission V: Commission V is the part of the IIW that addresses quality control and quality assurance of welded products, and thus its main focus is in the field of non-destructive testing, or NDT. It is the only such group within the IIW concerned with NDT, with all of the other commissions focused on joining technologies and their associated fields.

The historical structure of sub-commission V is shown in Figure 1, with the leaders of sub-commission VC shown along the middle line. Originally, this commission was organized as a single entity that encompassed all of the NDT disciplines as they pertained to welded products. Just before 1960, this structure was divided into sub-commissions VA, VC, VE and VF, which are described in Table 2. This allowed the study of these topics to be done in independent groups and thus to be lead by separate personnel. There were also a number of working groups that were established as part of this structure. Working Group 2 was focused on inspection of off-shore welded construction and Working Group 3 eventually became sub-commission VB, which is focused on technical aspects of quality assurance and development of NDT tools to monitor joining processes.

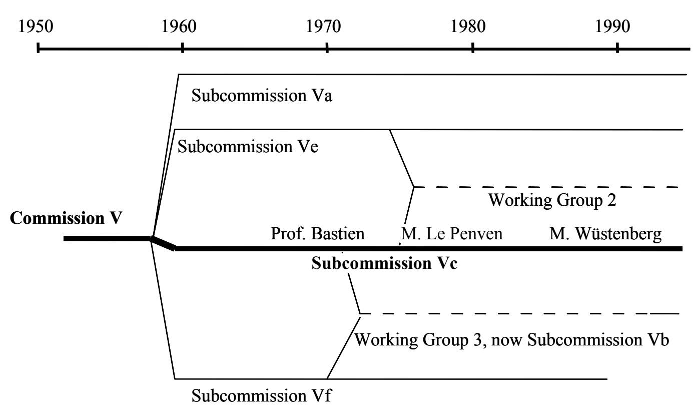

Figure 1: Sub-commission VC Historical Structure

Sub-commission VA is focused on radiographic inspection of welded joints, and it has been very active in the area of digital radiography. In particular, this sub-commission has made contributions in the areas of standardization and code acceptance of digital radiography techniques. There have been significant issues with acceptance of digital radiography for code inspection, and personnel within this sub-commission have been active in determining the boundaries of this technology. In particular, there have been issues with determining the density of digital images and in how to ensure the images can be securely stored on a media that is free from the potential of image manipulation.

Sub-commission	Description
VA	Radiography Based Weld Inspection Topics
VB	Technical Aspects of Quality Assurance and Development of NDT Tools…
VC	Ultrasonically Based Weld Inspection Topics
VE	Weld Inspection Topics Based on Electromagnetic and Optical Methods
VF	Weld Defects and Their Significance

Table 2: Sub-commission Structure of Commission V

Sub-commission VB has not been active recently and sub-commission VC is focused in the area of ultrasonically based weld inspection, which is the topic of the remainder of this paper. Sub-commission VE is weld inspection based on electrical, magnetic and optical methods and has been active in recent years. The main topic that this sub-commission has been working on is Magnetic Metal Memory (MMM), which is an NDT technique that measures residual magnetic fields in welded products to determine areas of high stress in welded joints. MMM was developed in Russia, and it has been used in many countries in the world as a quality assurance technique. There are three MMM documents that were accepted during the 2003 IIW Annual Assembly that were put forward to ISO for acceptance. Lastly, sub-commission VF is active in the area of identifying the significance of defects in welded joints. This is always an issue with inspection techniques when a flaw is found. The question arises about the probability of detection of weld flaws with different NDT methods, the accuracy of the flaw sizing measurement and then how this information can be used for a fitness for service evaluation.

Commission V is also in the process of becoming active in other areas. One initiative that is currently being evaluated is to work with Commission XI on a pipeline inline inspection (ILI) working group, which is an area of interest in the pipeline field. This would address the potential of ILI tools to detect and characterize certain types or in-service flaws, and would have overlap with a number of the current V sub-commissions.

Sub-commission VC: Sub-commission VC is focused on ultrasonically based weld inspection topics. This is a broad field that has been in existence for quite some time. Technicians have used the practical aspects of ultrasonic inspection for many years in the field for a wide variety of industrial applications. Ultrasonic inspection has also been a major topic for research institutions as the field attempts to refine the flaw detection and sizing capabilities of various ultrasonic techniques.

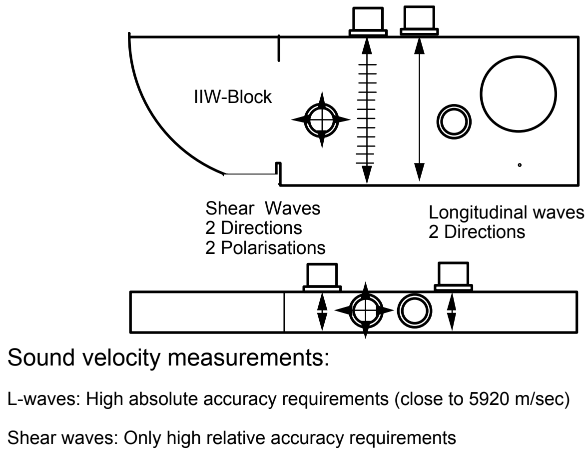

Figure 2: IIW Block

Likely the best known project that sub-commission VC has been involved with is the construction of the ISO 2400 - IIW block. This block is shown in Figure 2, and it is used for a wide variety of applications in many quite diverse ultrasonic settings. By using the known sound path towards the far curved surface, UT transducers are calibrated both for their zero point and the speed of sound. When performing zero degree measurements, there are three known sound paths that can be used to calibrate the transducer depending on the thickness of material being inspected. There is also the provision to determine the exit point of a shear wave transducer by directing the sound at the curved surface and measuring the index point. The angle of sound that the transducer produces can also be determined by using the calibrated angular measurements on the block. There are also a number of other sensitivity settings and calibrations that can be done using the IIW block.

It can thus be seen that the IIW block is quite versatile for field technicians and is an invaluable reference block to have. However, there are some issues with the IIW block that sub-commission VC has been discussing for quite some time. This began with a critical review article published by Mr. Hotchkiss of Panametrics on the IIW block in 1991[2], which started an IIW discussion on the metallurgical properties of the IIW block. Although all of the geometry and the machined reflectors are well known, there appeared to be some inconsistency in the definition of the materials characteristics. It was felt that the velocity and attenuation properties of the block must be more clearly defined, along with the allowable anisotropy in the block. For the majority of NDT applications, the variations found in the IIW blocks would be of no real consequence, but for some critical applications these effects were expected to be significant.

Out of these issues came a number of measurement techniques to improve the consistency of the IIW blocks. The first was to measure the LW and SW velocities of the block in a number of directions, as shown in Figure 2. This would ensure that the velocity, and thus the metallurgical properties are consistent between IIW blocks. It was felt that this would be done to a stricter standard than that of ISO 2400, which allows as much as a 50 m/s variation in the velocity[3]. There were a number of proposals for measuring the attenuation in the material, including a full skip V method, a double skip W method and a S/N technique. There were also a number of other measurements proposed that would deal with minimizing in-homogeneities in the material, chemical composition, etc of the blocks.

This issue was discussed for a period of time within the IIW, but it proved difficult to formulate a relatively simple and inexpensive test that the manufacturers of the IIW blocks could easily perform in their facilities. This project will be re-opened soon to move towards a conclusion of how best to perform these measurements to improve the IIW block consistency.

Automated Ultrasonic Inspection: The field of AUT has been progressing for quite some time now without the existence of good standard operating practices. Although all of the manufacturers of AUT equipment have guidelines and best practices for operating their equipment, there does not seem to be an independent document that addresses these needs. One of the two large projects that sub-commission VC has been working on recently is the formulation of a Handbook for the Automatic UT of Welds. This has been an initiative led by a German group, and the document is close to being finished and published as an IIW handbook. This handbook will have a set of best practices in it for AUT inspection and some examples from various industries, but it will not address AUT rejection criteria.

Rejection criteria for AUT are now being addressed in job specific ECA type criteria, and in ASME Code Case 2235. The later is a fairly general set of guidelines that can be applied to AUT systems that provide acceptance criteria for pressure vessel inspection. There is also a standard being worked on by a group within the DOT in the USA that will include rejection criteria as they apply to bridge inspection.

The AUT handbook is organized into sections that provide guidance with the various issues that must be addressed when performing AUT. The first several sections of the handbook address the generic requirements of AUT systems and the issues that must be addressed before starting the inspection. Included in this are the probe characteristics, S/N ratios, required data density, PRF, multiplexing systems, material feed velocity (for in-line systems), environmental conditions, material conditions and material geometry. All of these parameters can be important when designing an inspection plan for a certain part. These initial sections also discuss the data archival requirements and there is a brief discussion of the reference block requirements.

Figure 3 shows an example of the sensor carrier of a 40-inch ultrasound ILI crack detection pig. This is an extreme example of a complex AUT system where all of the probes must be controlled remotely while the pig travels down the pipeline. In this case, it is essential that the above-mentioned parameters be well known before fabricating such an expensive device.

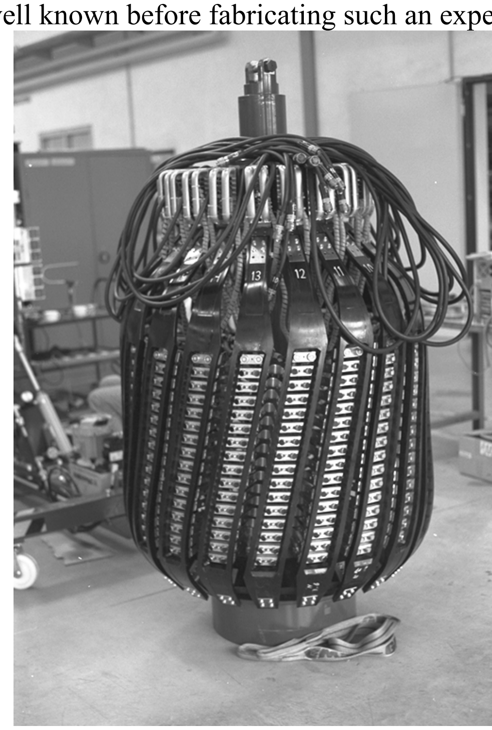

Figure 3: Ultrasound Crack Detection Pig

The next section of the handbook goes into detail on the required components of the AUT system. Included in this section are the probe choice, amplifier/receiver combinations, data management, data representation, process control, coupling techniques, and systems checks. There is a

significant amount of knowledge in this section that can be quite useful in many inspection configurations.
The last sections of the handbook deal with performance tests, test documentation and examples of AUT inspections. The examples are of particular interest, as they encompass such a wide range of real world applications of AUT. These examples include inspection of laser welds, thick steel plate, high speed train wheels, reactor welds, steel billets, large diameter pipelines, shafts and aluminium pipes.
Figure 4 shows a mechanism for inspection of the high speed train wheels. The demands of this inspection required a low inspection time, which meant that the wheels could not be removed from the trains during inspection. The solution to this, as shown in the figure below, was to build a hydraulic system on a maintenance track that could raise the train and spin the wheel in place. The inspection system was then able to take synchronous measurements with as many as 42 ultrasonic probes to detect flaws in the wheels. These probes were able to detect both volumetric flaws in the wheel and surface breaking cracking at the outside surface. The test requires one revolution of the wheel, and takes about 30 to 45 minutes per wheel set, which includes all of the time required.

Figure 4: Inspection of High Speed Train Wheels

The IIW handbook for automatic UT will be a useful document when it is published since it will encompass the experience of a number of experts involved in AUT inspection all in a single document. There are many documents and books that have AUT sections included, but invariably these are incomplete, as they do not address enough AUT details to allow a person to configure an inspection. The IIW handbook in many ways alleviates this by keeping the focus on AUT, and thus producing a publication that contains much of what is needed in most configurations in order to set-up and perform AUT inspections. The expected publishing date is in mid-2005, when it will be available outside of the IIW community.

Austenitic Weld Inspection: The other main initiative being worked on right now is a revision of the Handbook on the Ultrasonic Examination of Austenitic and Dissimilar Welds. This handbook was originally completed in 1986, but there were issues that arose since this time that necessitated a second edition. These include issues like inspection of duplex materials, in-service inspection, common fabrication flaws in austenitic materials and the benefits that can be gained from using horizontally polarized shear waves.
As is generally appreciated in the NDT community, ultrasonic inspection of authentic welds can be quite difficult. For fine grained carbon steel materials, the behaviour of the sound beam is predictable and consistent. Therefore, the angle, the focal properties, the attenuation and the frequency of sound introduced into the material are fairly predictable as it propagates through the medium. This makes determining the locations of flaws in the welds, and ensuring that the entire area of interest has been inspected relatively easy compared to austenitic materials.

Unlike for fine-grained carbon steels, in austenitic materials the beam angle, beam width and the sensitivity of an ultrasonic beam for flaw detection depend on the wave mode and the beam to columnar grain angle. This can cause severe problems when inspecting a weld, as the sound beam angle and direction, and thus its sensitivity to weld flaws can change. Among other issues that can arise, this can lead to situations where there are certain areas of the welds that are not being inspected, or to situations where the sound beam has been channelled away from the area of interest. The handbook for austenitic inspection deals with these issues and describes a best practice for inspecting austenitic welds. It also provides the same guidance with dissimilar metal welds, duplex materials and clad components.

The first section of the handbook describes how the parent material and the weld type effect the inspection. It also discusses the effects of welding methods and material types on the ability to inspect the welds. All of these parameters can play a critical role in determining the best way to inspect the weld. The two next sections deal in detail with the propagation of ultrasound through austenitic welds and how these variations in propagation effect the inspection. These are of primary importance when starting to design an inspection procedure for an austenitic weld in order to provide for the weld inspection coverage required by the application. Included in these sections are beam deviation, defocusing/focussing and scattering effects that can come from the grain structure of austenitic materials. In terms of the ability to inspect the welds, these sections describe how the welding position, welding method, weld repairs and types of defects effect their detection using ultrasonic testing. There is also a table that details techniques for detection of certain weld flaws. The last section outlines a generic procedure for inspection of austenitic welds. This is an excellent section that holds much of the relevant information that a person would need to write a procedure for inspection of these types of components.

The IIW Handbook on Austenitic weld inspection has been in circulation since 1986, and has been a good source of information for practitioners. It is expected that the current revision will be completed in 2005, and it will have more information than its predecessor.

Future Plans: Sub-commission VC will remain active in the area of ultrasonically based weld inspection techniques as directed by the experts in the IIW. There are always new methods being developed that have a requirement for a best practices document to help practitioners in the field. The plans for the immediate future will be to complete and publish the Handbooks on Automatic UT of Welds and the Handbook on Austenitic Weld Inspection. The next priority will be to get closure on the IIW project and devise an effective and simple enough test to ensure homogeneity of the IIW blocks.

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References:

1. See www.iiw.org for more detail on the composition of IIW.
2. Hotchkiss, F.H.C., IIW Document VC-894-91/OE.
3. ISO 2400.